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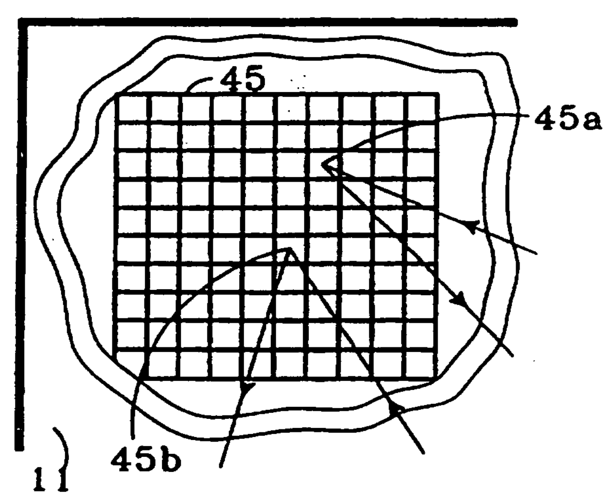
(54) Title: PROJECTION SCREEN

(57) Abstract

A screen for projection (11) being made out of an irregular surface (43), which is either light-absorbing or has been coated with a light-absorbing film (42), which in turn has been coated with a filter (41), wherein the Fourier transform of the irregular surface (43) can provide a significant spectrum with considerably higher frequencies than the frequencies which are obtained at Fourier transformation of the higher pixel structure projected on the picture and wherein the reflection factor (8) for the filter (41) is higher for the wavelengths which correspond to the wavelengths of the illuminating light (R, G, B), than for the wavelengths being outside the wavelengths of the illuminating light.



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TITLE:
Projection screen

TECHNICAL FIELD:
The invention relates primarily to a projection screen as stated in the preamble of the enclosed Claim 1.

One aspect of the invention thus relates to a projection screen intended to reduce poor contrast during projection with narrow band light sources.

BACKGROUND OF THE INVENTION:
There are already several projection arrangements for projection of video pictures on LCDs on the market. These projection arrangements, however, have not been very successful, due to several inherent drawbacks.

One of the drawbacks of the known projectors is that they offer deficient viewing ergonomics if, for instance, the projector is placed in a room at a position corresponding to half the width of a vertical wall onto which the picture is to be projected, and the projector furthermore is situated at a level corresponding to the viewer's eye level. In that case, the projected picture's centre will be situated at the corresponding height and width on the vertical projection surface, so that the projector or the viewer will obstruct the picture. It would therefore be desirable to offer a projection construction that provides a parallel shifting of the projected picture, so that the projector can be placed next to the ceiling, the floor and/or on a side wall.

The illumination arrangements have a common focal area, which in the orthogonal projection towards the respective image generating device primarily is situated in the centre of the respective IGDs, so that said deficient viewing ergonomics arise.

Yet another limitation of today's TV projectors is that they only allow projection of two-dimensional pictures. There are methods known which provide projection by alternately showing a right and a left registered picture and at the same time mechanically switching the polarisation filters between two orthogonal polarisation directions, whereby the viewer is able to see three-dimensional pictures through the use of polarised glasses having orthogonally polarised glass. The use of mechanical devices imply considerable disadvantages, such as disturbing noises, and increased power consumption, volume and weight.

It is, of course, possible for persons who normally wear glasses while watching TV, to have their glasses for the right and left eye, respectively, designed so that they render a, between themselves, orthogonal polarisation. It is then advisable to not choose horizontal, respectively vertical polarisation, neither in the projector nor in the glasses, which polarisation due to reflection, can produce stress for the left and the right eye while watching natural sceneries.

A serious limitation of today's projection arrangements is the imperfect colour reproduction. The area of the colour diagram that is defined by the three primary colours is not sufficient for a good reproduction of colours – especially in nature.

By using laser or laser diodes as illumination sources, there is a risk during projection that very disturbing speckles in the picture are generated. Existing solutions have considerable disadvantages, which either cause the necessity to use mechanically movable components – for example a rotating diffuser next to the object plane, or that a spectral broadening of the light takes place, as is

the case during modulation of the laser illumination source. In the case of the rotating diffuser it is also difficult to produce enough speckle reduction without impairing the resolution of the picture, due to the fact that the diffusor cannot be placed sufficiently close to the object.

Since there are frames around the pixels in the IGD, there is the disadvantage of a visible pixel structure in the picture.

On the market today there are many types of projection screens, which are partly of the spectrally broad-banded type and partly of the principally, in relation to the screen, centrally illuminated type.

In the case where the projector is strongly shifted to one side in relation to the projection screen, special demands are set up as to how the screen should reflect the light to the viewer's eyes.

In the case where the projection screen is illuminated with light in a number of narrow bands, there are today no narrow-banded illumination sources which are bright enough to obtain sufficient contrast in the picture at normal in-door lighting. This problem is especially relevant to a new type of display, i.e. the DMD, Digital Micromirror Device, which is described in the article "The Digital Micromirror Device (DMD) and its transition to HDTV" by the authors J.M. Younce and D.W. Monk in "The 13th International Display Research Conference", Strasbourg, August 31-September 3, 1993, pp 613-616. It is hard to, for practical reasons, in the DMD create colour projection by implementing room-multiplexing, i.e. to generate picture information in spatially separated parts in the display unit(s). One is then forced to use time-multiplexing,

which means that the same parts of the display unit are used for reproduction of the different colours. The problem is now solved by using a rotating colour filter which is transilluminated by a lamp. This is, considering the light efficiency, a highly unfavourable solution. By instead implementing narrow-banded, fast-switching illumination sources, such as laser diodes, one would obtain a less complex and a more efficient arrangement.

A solution to the above mentioned problem is described in PCT/SE94/00253, indicating how a mirroring diffusor can be coated with a selectively absorbing layer, to reduce the reflection of surrounding light from the screen and thus increase the contrast in the image. The present invention will give further improvement by for example using an absorbing diffusor covered with a selectively reflecting layer.

Today's projectors with only one projection lens can generally be divided into two main categories. In the first category there are several IGDs which are each submitted to transillumination by one-coloured light with a different colour light for each IGD. The light from the different IGDs is then linked together via a dichroical linking device consisting of dichroical mirrors, for example in the form of a dichroical prism.

In the second category there is only one IGD, transilluminated by a broader spectrum. There are then different colour filters in the adjacent image elements which produce colour pictures. This second category therefore has the great disadvantage of considerable loss of light through the filtration of the image elements. This process also produces a heating of the IGDs, which can be substantial because of the often large luminous flux. Later on we intend to show designs of projectors in this

category that do not have the mentioned disadvantage of light-loss in the colour filters. We will henceforth mainly limit this discourse to projectors in the second category – even though, as is stated below, it is applicable even on projectors in the first category.

SUMMARY OF THE INVENTION:

A general purpose with different aspects of the invention is to substantially reduce the above mentioned problems with poor contrast during projection with low effect, narrow-banded illumination sources.

The purpose of various aspects of the invention is obtained through the projection arrangements which are stated in the appended independent claims.

The further purposes with other aspects of the invention are obtained through the embodiments of the projection arrangement that are stated in the appended dependent claims.

An aspect of the invention is based on the projection arrangement which includes a number of IGDs, for instance LCDs, or more generally SLMs (Spatial Light Modulators), for off-axis projection on a screen with one projection lens, which are illuminated by several, for instance, three differently coloured light sources that have possibly been obtained through colour separation of light from a single light source, a shared projection lens in the ray path after the out-put of the IGD, and a focusing illuminating optical system whereby the projection lens is situated in or at the shared focal area. In light of the above stated facts, one aspect of the invented projection arrangement is mainly characterised by that the illumination arrangements' said shared focal area is situated, so that its optical orthogonal projection against the plane in which the IGD is

located is substantially shifted from the centre of the IGD, whereby the projected picture obtains a parallel displacement, thus rendering the desired ergonomical advantage. Laser diodes are the for this purpose best suited illumination sources because of their narrow spectral band width. A particular advantage with such an arrangement is that the projection picture can be made particularly light-intensive and that a good function and viewing ergonomy can be provided.

According to a first embodiment according to one aspect of the invention, light is directed at different angles of incidence from the various illumination sources against the IGD. The light first hits a positive microlens matrix with a positive lens for each of the different colour groups which together form an image spot and that focus the various colours towards separate negative tilted microlenses or microprisms, which focus the light through the middle of the respective colour pixel elements. A tilted microlens is defined as a microlens that is deflecting a through the middle of the lens passing light ray, so that the deflection is different from the deflection that a light ray should have if the tangential surface at the middle of the lens were parallel to the plane of the microlens matrix itself. At the exit of the IGD there are matrices of microlenses, microprisms and/or diffractive optical elements (DOEs) to focus the light into the entrance pupil of the projection lens according to one aspect of the invention's principle. The first matrix on the out-put side consists of positive microlenses collimating the from the pixel apertures coming light. The second matrix consists of microprisms deflecting the light into the middle of the entrance pupil of the projection lens. The two microlens matrices on the entrance side can be placed on either side of a sheet of glass. The microprisms are having the same purpose as a very compact

colour corrected field lens. The second matrix with tilted microlenses on the in-put side may very well be affixed directly onto the substrate on the in-put side of the SLM. This is especially the case if the microlenses or microprisms are produced for example by etching. Techniques for etching of microlenses on glass exist. The same is true also for the first matrix on the out-put side of the SLM. The latter matrix can moreover be the only one on the out-put side if the lens and prism operation is integrated into one and the same matrix with refractive or diffractive elements.

The above stated technologies of using microlens matrices is also applicable on the projectors in the first category by instead using a positive microlens on the entrance side for each pixel.

According to a second embodiment, the microlens array principle is combined with a field lens, which focuses the light on the out-put side of the IGD according to one of the invention's principles. It can be difficult to achieve a satisfactory colour correction in the field lens as it has to bring about big changes in the field angles. It is therefore advantageous to compensate the colour aberrations in the field lens with the prismatic elements in the microprism array.

One of the fundamental principles in achieving the purposes of one aspect of the invention is using time multiplexing possibly in combination with spatial multiplexing by, in one and the same IGD, using pixels dedicated to different colours - either by using a colour separation technology or by allowing light to be blocked in cells that do not have the colour for which the cell is dedicated.

The term time multiplexing refers to the fact that video information is divided up in time so that one picture is sent to the IGD in multiple in time separated partial pictures, where each of these partial pictures reproduce the picture information for a number of colours.

The ordinary colour systems for television are, for different, partly historical, reasons not very efficient. This is partly due to having to work with the at the time existing phosphors, which left large parts of the colour diagram uncovered. In particular, large parts of the green, more saturated colours are poorly reproduced. It is therefore a special purpose of one aspect of the invention to provide an improved colour reproduction. According to the C.I.E. colour system from 1931 are the current colour co-ordinates according to both the European system EBU and the American NTSC, drawn up in a diagram, evidently completely insufficient for all saturated colours and especially in green, where the colour tolerance, however, is bigger. Even with the transition to monochromatic illumination sources, which are known to represent maximal colour saturation and thus are on the borderline of the colour diagram according to C.I.E., can a great improvement be achieved. This is already possible using today's laser sources, which within the near future will be improved and less expensive. Much of the documentation is, however, already registered with the old basic colours, and one would like to reproduce this documentation with compatibility. There is the possibility to extrapolate by elongating the vector from the white point in the diagram in order to reproduce colours, which according to the registered values are close to the limiting triangle, with points that are outside.

The improvement that is possible by using monochromatic colours, can according to one aspect of the invention's

principle, be improved further by using more than three colours. According to the principle for metamerics are the sense of seeing and the brain thus constituted that the brain cannot make out the difference between two stimuli, even if they are physically different, but sees the same colour nuance although the spectral division is different, and it is therefore possible to reproduce one single, subjective impression in many different ways. Every imaginable colour impression is theoretically defined to the colour (consequently not considering the intensity) of a point in a two-dimensional colour diagram, because of which two parameters are enough for the colour information. Ordinary television, of course, transfers information for each pixel through one intensity parameter and two colour parameters. From the ordinary colour diagram, however, it is clear that it is impossible to cover all observable colours with three colours, no matter how they are chosen, and it is therefore preferable to use monochromatic colour sources and to work with more than three, preferably four, five or six, different colours.

A disadvantage with the known projectors is then that they have a severely limited colour dynamics (gamut). This largely depends on the fact that only three colours are used to generate the picture wherefore it is impossible to with good efficiency reproduce colours of down to 400 nm and up to 700 nm. Should one expand the number of colours in a projector in the first category, one would have to, using today's technology, expand the number of IGDs with as many as the number of colours, thus making this kind of projector even more expensive. Should one expand the number of colours in a projector in the second category, one would, using the existing technology, worsen the already poor light efficiency.

In accordance with a first embodiment, according to one aspect of the invention, according to the second category the single IGD is illuminated with different time multiplexed illumination sources of different colours. The illumination sources are directed in correlation with the picture information to the IGD so that the information of a certain colour is generated via the IGD when said colour illuminates the IGD. One hereby obtains the possibility to with very few pixels generate pictures with a very good colour reproduction.

In accordance with a second embodiment, according to one aspect of the invention, according to the second category the single IGD is used for both spatial and time multiplexing. The time multiplexing is generated in the manner stated above, while the spatial multiplexing is generated by colour separation implementing microlens matrices according to the above stated two principles. It is in this way possible to produce a picture using, for instance, a gamut between six primary colours with, for example, three colour pixels which each are transilluminated by two colours that are close in the spectrum and are sequentially alternated in time.

It is possible to utilise a gamut in a display which is larger than the gamut that is rendered by the camera or the equivalent received video signal. According to one aspect of the invention this is achieved in the following manner.

One first decides the gamut G_r that is needed to reproduce the in normal sceneries occurring colours. The received signal's gamut is designated G_c. The display's gamut is designated G_d. All three gamut areas are supposed to have a mainly shared achromatic point x_n and y_n. The received signal supposedly has the colour co-ordinates x_c and y_c located within G_c. The colour co-ordinates for the

received signal's dominant colour is calculated as the point where a line through the points x_n,y_n and x_c,y_c crosses the edge of G_r and is designated x_b and y_b.

The colour co-ordinates x_{bc},y_{bc} for the point of the edge of G_c which makes up the point of intersection between the edge of G_c and a line through the achromatic point x_n,y_n and the point x_c,y_c in the colour diagram is calculated. The colour's excitation potential p_{re} is determined as:

$$p_{re} = 1+k_{re}*((x_b-x_n)/(x_{bc}-x_n)-1) \quad (1)$$

or

$$p_{re} = 1+k_{re}*((y_b-y_n)/(y_{bc}-y_n)-1) \quad (2)$$

where k_{re} is chosen in the interval {0,1}

When k_{re} which is from now on called the colour expansion factor, equals 0, is the colour reproduction the same in the projector and in the by the camera registered image. When kre equals 1 there is maximum colour expansion. The possibility of choosing the k_{re} within said interval should be given in the projector's control unit.
New, to the intersection $G_r \cap G_d$, between the gamuts G_d and G_r expanded colour co-ordinates x_r,y_r are calculated as:

$$x_r = p_{re}*(x_c-x_n)+x_n \quad (3)$$

$$y_r = p_{re}*(y_c-y_n)+y_n \quad (4)$$

If the number of primary colours in the display is larger than three, then the relative light intensities are not distinctly determined but can be chosen freely from a metametrical area with combinations of primary colours that

render the same colour co-ordinates x_r, y_r. It is therefore possible to divide the by the different colours generated gamut into a number of non-overlapping triangles, which are limited by the points of the different light sources in the colour diagram. Every point in the picture can thereby, at a certain point in time, be represented by light from a maximum of all three light sources which generate the triangle in which the point's colour co-ordinates, or expanded colour co-ordinates, are located. Generally speaking, will the number of triangles equal the number of different-coloured illumination sources minus two.

In general, at least three light sources can be used in order to represent a given point p0 with the coordinates (x0,y0) in the colour diagram. In principle, the luminous flux Φ in lumen is maximised for the point p0 (or the inverse of the luminous flux is minimised for said point).

$$\Phi 0 = 683 * \sum_{i=1}^{m} a_i * S_i * y_i \text{ lumen} \qquad (5)$$

with the constraints:

$$\sum_{i=1}^{n} (a_i * S_i * x_i - x0 * (a_i * S_i * x_i + a_i * S_i * y_i + . \, a_i * S_i * z_i)) = 0 \qquad (6)$$

$$0 \le a_i \le 1, \; i = 1,n \qquad (8)$$

$$a_i = 1, \; i = n+1,m \qquad (9)$$

where:

m is the total number of light sources, $m \geq n$;

n is the number of light sources to be used to represent a certain colour, $n \geq 3$;

S_i, $i = 1,n$ are the powers of the light sources in Watt;

(x_i, y_i, z_i), $i = 1,n$ are the tristimulus values for the n laser diodes;

a_i, $i = 1,m$ indicates the maximal transmission for the different light sources and for point the point PC in the colour diagram.

The luminus flux in a pixel or group of colour pixels is then determined from a product of the luminance value of the video signal and the vector a_i ,$i = 1,m$.

G_c is a convex polygon where the corners are given by the primary colour co-ordinates, which are determined by the camera. This facilitates the calculation of the point x_{bc},y_{bc} which simply can be calculated as the intersection of two straight lines. To facilitate the calculation of the point x_b,y_b it could be suitable to approximate the edge of $G_r \cap G_d$ with a number of straight lines, which together form a polygon G_{rr}. The point x_{bc},y_{bc} can formally be calculated as:

$$x_{bc},y_{bc} = \mathrm{Min}(\mathrm{Abs}(x_i-x_n))\cdot\mathrm{Sgn}(x_i-x_n)+x_n, \mathrm{Min}(\mathrm{Abs}(y_i-y_n))\cdot\mathrm{Sgn}(y_i-y_n)+y_n \quad (10)$$

$$\text{for all } i = 1,n$$

where x_i, y_i for i = 1 to n, are intersection points between the n lines which define the area G_c and the line which passes through the points x_n, y_n and x_c, y_c. Abs designates the absolute value and Sgn designates the sign (+ or -1).

The point x_b, y_b can be calculated analogously.

According to one aspect of the invention the visual impression of speckles in the picture is eliminated by placing a dispersive window (a despeckelator) for example based on the PDLC-technology described in the article "Field Controlled Light Scattering From Nematic Microdroplets" by the authors J.W. Doane, N.A. Vaz, B-G Wu and S. Zumer; Applied Physics Letters 48, 269 (1986). By generating an in time varying spread in the dispersive window, the light will reach the eye from one picture point with an in time varying phase-relationship and one gets an in time varying speckle pattern that is integrated by the eye as a speckle-free image. If, for instance, the distance between the entrance pupil and the IGD is 35 mm, it is enough if the angle spread has a standard deviation of about 0.15 degrees in order for one ray in to the despeckelator to obtain a standard deviation of about 90 degrees to the eye. If one varies the angle spread in the despeckelator with a frequency of about 60 Hz, the eye integrates all speckle patterns to a uniformly lit surface. By using a finite distance between the despeckelator and the IGD, one also obtains a certain broadening of the pixel apertures in the IGD. This causes a reduction or an elimination of the pattern of the pixel frames. It is therefore correct to say that the despeckelator also functions as a depixelator.

In order to reduce light reflection from surrounding illumination sources on the screen and the resulting poor contrast in the picture, it is possible to coat the screen

with a light-absorbing layer on which a filter is placed (for instance a thin-film filter), which has high reflectance for the wavelengths where the light that passes the IGD has a high intensity, and which has a high transmission for the wavelengths where this light has low intensity. This is, of course, easiest to do where the illumination sources are very narrow-banded. For a three-colour projector can then such a filter be designed as a filter between two bands with high transmission between the blue and green colours, and between the green and red colours. In a preferred design is the screen shaped as a diffuser with a light-absorbing coating on which the thin-film coating is applied. The irregular or diffuse surface is shaped so that its Fourier transform mainly renders a significant spectrum with considerably higher frequencies the frequencies which are obtained at Fourier transformation of the on the picture projected pixel structure. It is obviously of great significance that the light which reaches the screen is reflected as efficiently as possible before reaching the eyes of the viewers. This is possible to achieve by designing the screen with microfacets or DOEs onto which a light-absorbing coating is applied, together with the above mentioned filter which mainly reflects the narrow light bands from the projector. The microfacets or the DOEs are designed so that light is reflected back within an angular area in which the viewer's eyes are likely to be. The screen will, of course, not have uniform qualities, since the angle of incidence of the light varies across the screen, and the viewer's eyes will be directed in different angular positions in relation to different parts of the screen. Within each pixel on the screen, there are a number of facets with both vertical and horizontal randomly tilted angles. The distributions of the tilted angles is calculated in consideration to incidence and the desired angular area for reflected light, and the number of mirror elements is chosen in

consideration to the diffraction, so that an even distribution of light is obtained. It would be possible to manufacture the screen with the help of embossing using moulds generated with the help of electron beam lithography or laser scanning. The diffusor can very well be modelled with micro-facets according to the above described principle. It is of course possible that the screen is manufactured with its irregular surface in a light absorbing material, at which the coating with the light absorbing layer can be omitted.

When the projector is positioned asymmetrically in relation to the projection screen, then the screen itself will be asymmetric with regard to the light spread distribution. This is for example the case when the projector is placed in connection to a normal to the screen emerging from a corner of the screen. To be able to use the one and the same screen with the projector placed in connection to each one of the corners of the screen, it is possible to model the screen such that it is possible to turn the screen upside down to be able to place the screen in connection to the diametrically opposite corner. A screen structure for the remaining two corners can be applied on the other side of the screen.

The principles for the different aspects of the invention in the above descriptions are in no way limited to only projectors in the second category, but are completely applicable on projectors also in the first category. Thus, for instance, a six-colour projector can be designed with three IGDs, where each IGD is illuminated by two colours, and where colour separation, on the analogy of the one shown in figure 5, is used. The advantage of not having to resort to time multiplexing, makes it possible to chose low power illumination sources and also results in a better colour saturation, since the illumination sources shine

without interruption. The latter can be of significance to the life of the illumination sources, since intermittent light in all probability cause a faster wear. In the same way it is also possible to design a four-colour projector with two IGDs and two illumination sources per IGD.

Different aspects of the invention will below be described as example cases with reference to the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS:

Fig. 1 schematically depicts a projector for 3-D projection.

Figs. 2 to 4 schematically depict different alternative positions of the polarisation-twisting window in 3-D projectors.

Fig. 5 shows the principle for a colour separation technology in an LCD-projector.

Fig. 6 schematically illustrates how one expands the of the camera given gamut to a realistic gamut.

Fig. 7 schematically illustrates how one expands the of the camera given gamut to a, with a polygon approximated, realistic gamut.

Fig. 8 schematically depicts the make of a IGD with a despeckelator / depixelator.

Fig. 9 shows a cross section of one part of the projection screen.

Fig. 10 shows in a diagram how the diffuse reflectance, with the help of thin-film technology, is designed in the

case of narrow-banded illumination sources.

Fig. 11 schematically shows the design of a reflecting screen with microlenses as the foundation for the in figure 9 illustrated coating.

Fig. 12 schematically depicts a six-colour projector where both spatial and time multiplexing are used.

Fig. 13 illustrates an example of the division of a six-colour gamut in four colour triangles.

Fig. 14 schematically illustrates a six-colour projector with two IGDs with three-colour separation in each of the IGDs.

Fig. 15 illustrates a preferred manner of choosing polarisation directions at the use of 3-D projectors.

Fig. 16 schematically illustrates the make of a 3-D three colour projector, where an off-axis field lens is used to direct the light into the projection lens.

Fig. 17 schematically illustrates a detailed study of an IGD with condensor, despeckelator/depixelator and field lens.

Figs. 18 to 21 illustrate different placements of the projector in relation to the projection screen.

PREFERRED EMBODIMENTS:

Fig. 1 schematically depicts a projector for 3-D projection. The laser diode light sources 2R, 2G, 2B can beside a number of laser diodes in the colours red, green and blue also include light distributing optics in the form

of for example diffractive optical elements (DOE) so that an even illumination of the IGD 1K is obtained via the condensor C. The light in the green colour generally incides with an angle W against the IGD 1K. The light in the red and the green colour incide with the angles E1 and E2 in relation with the to the green colour whereby one in the IGD 1K obtains the colour separation described below in connection with figure 5. Via the connections V and H to the unit U1 picture information comes in with right and left stereo pictures. From the unit U1 proceeds alternate left and right pictures via I1 to the IGD 1K. At the same time the polarisation alternates 90 degrees in the window L1 with liquid crystals on an impulse from U1 via S1. The light from the IGD K1 passes first a polariser P1 and then the polarisation twisting window L1. Consequently, the light that proceeds from the IGD with a left picture at the passage through the projection lens 7 on to the screen 11 will have an orthogonal polarisation against the polarisation for a right picture. When then the viewer of the picture wears in the same way orthogonally polarised glasses he will experience a three-dimensional picture. If the IGD already contains a polariser and an analyser, the polariser P1 can be left out. If the provided video signal, via VH, already comes in alternating left and right pictures, the unit U1 is simplified to give only the necessary alternation impulses to the polarisation alternating window L1. The projector has here been depicted in projection that could be a side projection. The projector can however be designed so that similar conditions also apply at vertical projection. The light from the illumination sources have been given the average incident angle W onto the IGD 1K in order to simplify the focusing of light to the projection lens 7. The angle W can be chosen within the interval 0 to AW degrees, where the angle AW is an average angle for the light that leaves the IGD 1K. To further facilitate the focusing of light in

the IGD 1K to the projection lens 7, the light from each of the light sources 2R, 2G and 2B can be either collimated after the passage through the condensor C, or convergent with angle of convergence CW that is in the interval 0 to OW degrees, where OW is the angle of convergence that the light has when it leaves the IGD 1K. In extreme cases where A=AW and the light after passing through the condensor has the angle of convergence OW, can the deflecting function in the matrix 22 in figure 5 be left out. Practically, it is suitable to chose a value for W in the interval of 0 to AW/2 degrees and a value for the angle of convergence for the light from the condensor C to picture generation element 1K that is in the interval 0 to OW/2 degrees.

Figs. 2 to 4 schematically illustrate different alternative ways to place the polarisation-twisting window L1 in 3-D projectors. The illumination source is designated with L, the IGD with 1, the projection lens with 7 and the projection screen with 11. The arrangement in figure 2 corresponds principally with the one in figure 1, with placement of the polarisation-twisting window L1 between the IGD and the projection lens 7. In figure 3 has the polarisation-twisting window L1 been placed immediately after the projection lens 7. Figure 4 represents a case of the illumination source generating polarised light for which the direction can be altered by a polarisation-twisting window between the illumination source L and the IGD 1.

Fig. 5 very schematically depicts a section of the IGD according to one aspect of the invention where colour separation is used, i.e. the different colours R, G and B are separated in the dedicated light valves 1R, 1G and 1B in an SLM 1. Green light is here thought of as inciding orthogonally against the IGD, i.e. the angle W in figure 1

is 0, while red light incides with the angle E2 and blue light with the angle E1. The light in the different colours first come in to a microlens matrix 322, with positive microlenses 94 with an effective focal length that is considerably larger than the distance A between the matrices 322 and 323, and at the same time considerably shorter than the distance B between the matrix 322 and the SLM 1. Light in the three different colours hit a negative microlens each, i.e. the microlenses 19R, 19G and 19B in a second microlens matrix 323 and are then focused to a light valve each, i.e. the valves 1R, 1G and 1B in an LCD matrix 1, whereby light in the three different colours hit the light-directing, possibly with diffractive structures colour corrected combinations 7R, 7G and 7B of microlenses and microprisms in the matrices 21 and 22. The microlenses in the matrix 21 have an effective focal length equivalent to the distance between the LCD matrix 1 and the matrix 21. The negative microlens 19G can be an ordinary on-axis lens. It is however, especially considering the diffraction and its influence on the contrast, necessary that the light is focused into the middle of all the light valves 1R,1G,1B in the SLM 1. Therefore the lenses 19R and 19B can be made out of a combination of prismatic parts and negative lenses, i.e. tilted negative lenses. In the general case, when the angle W in figure 1 is not zero, all the negative lenses in matrix 323 are tilted. It is certainly possible to shape the lenses 94 as well as the lenses 19R, 19G and 19B, as diffractive optical elements. The two matrices 21 and 22 can at advantage be combined into one matrix, either as refractive elements, which is especially suitable when the illumination sources have a spectrally narrow band width, or as diffractive optical elements . In the case of the light valves 1R, 1G and 1B being dispersive, for instance of the PDLCD-type, there is no need for a polariser or an analyser. The light transmission will hereby be three times as efficient.

In this figure a possible arrangement is shown, where negative microlenses are used in the second matrix. It is of course possible to model this matrix with only prismatic elements, at which the focal length of the positive microlenses in the first matrix mainly will equal to the optical distance to the pixel apertures to which the light from the microlens in question shall be linked with help of the prismatic elements in the second matrix.

Fig. 6 schematically illustrates how one expands the of the camera given gamut G_c into a realistic gamut G_r during reproduction with a 6-colour display with the gamut G_d. CIE designates the CIE colour diagram. x and y designate the co-ordinates in the CIE. A colour c in the camera's gamut G_c is expanded to the colour r in the realistic gamut G_r.

Fig. 7 schematically depicts how one expands the of the camera given gamut G_c into a with a polygon approximated realistic gamut G_{rr}. A colour c in the camera's G_c is expanded to the colour r in the with a polygon approximated realistic gamut G_{rr}.

Fig. 8 schematically illustrates the design of an IGD with a despeckelator/depixelator. The light valves in the IGD are designated with lV, the from figure 5 integrated matrices 21 and 22 are designated with MM, while the despeckelator window is designated with 88 where a light distribution with the standard deviation of DV is obtained. When the light distribution is varied by putting an alternating voltage device VA of suitable amplitude and sufficient frequency, and which is superimposed on a DC device VD (which is needed for minimal dispersion) on the despeckelator window 88, then will the phase of the light which reaches the viewer's eyes vary in such a way that the visible impression of a speckle pattern is integrated out.

The angle DV is chosen so that the standard deviation of the phase changes amounts to at least 90 degrees. The frequency of the phase changes should amount to at least 60 Hz. One can easily see that the despeckelator window also will broaden the visual impression of the pixel aperture and will also therefore function as a depixelator. Because the light from different parts of the IGD incides with different angles on the window 88, it would be suitable to divide it into different segments with between themselves varying values on both the direct current component VD and the alternating current component VA.

Fig. 9 shows a cross section of a part of the projection screen 11, which for example can be constituted by an irregular surface 43 which can be light-absorbing or for example coated with a light-absorbing layer 42, which furthermore can be coated with a filter 41, wherein a Fourier transform of the irregular surface 43 generally may provide a significant spectrum with frequencies which are higher than the frequencies obtained from a Fourier transformation of the pixel structure projected on the picture. Furthermore, a reflection factor 8 for the filter 41 can be high for those wavelengths which correspond to the wavelengths R,G,B of the illuminating light, whereas the reflection factor can be lower outside these wavelengths, i.e. the wavelengths R,G,B of the illuminating light appear more clearly than the wavelengths which are outside the wavelengths of the illuminating light.

Fig. 10 shows how the diffuse reflection factor for the screen is to be optimally designed, using thin-film technology. The axis r is graduated in a diffuse reflection factor while the axis 1 is graduated in wavelength, with the wavelengths in the illumination wavelengths R, G, B marked. The curve 8 shows the diffuse reflection factor, which is obtained by, for example,

coating a diffuse light-absorbing surface with a thin-film filter which transmits between the colours B and G, respectively G and R. The curve 8 could therefore also show the reflection factor of the thin-film filter, where the axis r is graduated in a reflection factor. Because the main part of the surrounding light which hits the screen, and which is located between the colours B and G, respective G and R, will be absorbed, the contrast of the picture will be considerably greater. It is, however, also possible to use this effect to reduce the brightness of the illumination sources in the projector, whereby important energy savings are obtained. Generally speaking, can the transmission curve 8 be designed so that mainly only the projected light wavelengths are reflected, while light with wavelengths outside of these mainly are absorbed by the screen. In order to obtain an obvious effect, should the relation between the reflection factor at the illumination wavelengths R, G and B, and the reflection factor for any wavelength between the illumination wavelengths R, G and B be larger than 1,4. If the spectral band width of the illumination sources is relatively small, it is possible to obtain an obvious improvement of contrast through the absorption of a considerable amount of the surrounding light into the projection screen 11.

Fig. 11 illustrates schematically the principle for design of the projection screen with microfacets which for example are arranged as a coating on a light-absorbing layer 42 on the screen. The facets 45 basically cover a pixel on the screen, wherein the distribution of the inclination of the facets can be, for example, randon. Furthermore, the inclination of the facets are within certain intervals which are chosen so that the light can be directed towards the place in the room where the eyes of the viewers essentially will be positioned, when the facets are first coated with an absorbing layer and then with a reflecting

layer, as is described in Fig. 9, light is thus reflected so that all viewers can see this pixel. Light which is reflected against mirror 45a obtains a different direction from the light which is reflected against mirror 45b. The number of mirrors and the distribution of angles is calculated with the diffraction in consideration, so that an even distribution of light is obtained to all presumptive viewers' eyes.

Fig. 12 schematically illustrate a six-colour projector where both time and spatial multiplexing are being used. The projector is mainly designed as the projector described in figure 1, with the following additions.

The six illumination sources with the appurtenant light distributing optics are grouped in three groups: 2r, 2R; 2g, 2G and 2b, 2B. In a preferred design are the illumination sources in each group chosen so that they are spectrally close. Light in each group is linked together with the help of dichroical mirrors 5a, 5b and 5c, so that the light in each group will incide towards the condensor C with the same angle relations. The video signal for each picture from the unit U1 is in the unit CU divided into two pictures with information respectively for the colours in the illumination sources 2R,2G,2B and 2r,2g,2b, so that when a picture changes from one colour group to an other are the illumination sources activated or deactivated via the connections 3 or 4. The division of colours in the different illumination sources is for the main part of the, by the six colours defined, gamut not entirely unique, i. e. there are a great number of combinations of the six light colours which are represented by one single point in the colour diagram. It is therefore possible to, as shown in figure 13, divide the, by the six colours defined, gamut into four non-overlapping triangles G1, G2, G3 and G4, which are limited by the six illumination sources' 2R, 2G,

2B, 2r, 2g and 2b points 3A, 3a, 3B, 3b, 3C and 3c in the C.I.E. colour diagram CIE. x and y are the designations for the co-ordinates in the C.I.E. colour diagram CIE. Every point, for instance CP, in the picture will thereby, at a certain point in time, uniquely be determined by light from a maximum of all three illumination sources which define the triangle, for instance G2, in which the colour co-ordinates or the expanded colour co-ordinates of the point are located. In general will the number of triangles equal the number of different-coloured illumination sources minus two.

Fig. 14 schematically depicts a six-colour projector with two IGDs and with three-colour separation in each of the IGDs. It is, from the illumination sources 2R, 2G, 2B and 2r, 2g, 2b up to the IGDs 1K and 2K respectively, designed in the same way as the device in figure 1, with the difference that the condensor is shown as if its optical axis were coinciding with the normal of the midpoint of the IGD. The light spectrum for the light sources in the groups 2R,2G,2B and 2r,2g,2b are mainly disjoint. The light from the IGD 1K is linked via the dichroic prism DS into a device on the whole equivalent to the one described in figure 1. On the output of the unit U1 is a unit CE, where colour expansion is performed in the case of the , via V and H or VH, incoming signal to the unit U1 has been registered with a smaller gamut than the projectors potential gamut. The unit U2, which divides picture information from the unit CE into two partial images in consideration to the colour contents, one via J1 for the illumination sources 2r,2g,2b and one via J2 for the illumination sources 2R,2G,2B. CC designates schematically a connection on the unit CE, by means of which the value of the colour expansion factor k_{re} can be determined.

Fig. 15 demonstrates a preferred manner of choosing

polarisation directions at the use of 3-D projectors. RE designates the right eye, and LE designates the left eye in a pair of glasses. The polarisation in the two glasses have the directions RP and LP, oriented in the angles RA respectively LA, which are given the values 45 respectively 135 degrees, or 135 respectively 45 degrees. The projected light naturally has the corresponding polarisation directions for right-, respectively left-registered pictures.

Fig. 16 schematically illustrates the design of a 3-D three colour projector, where an off-axis field lens FL is used to direct the light into the projection lens 7. The design is in other respects the same as illustrated in figure 1, with the difference that the condensor is shown as if its optical axis were coinciding with the normal of midpoint of the IGD. The field lens may very well be combined with the prismatic matrix 21 in figure 5, whereby means to colour correction of the colours from the light sources 2R,2G,2B are given.

Fig. 17 schematically illustrates a detailed study of an IGD with condensor C, despeckelator/depixelator 88 and field lens FL. The matrix ML can either consist of only positive microlenses or a combination of positive microlenses and microprisms with little prismatic angle, where the prisms are used to correct the colour aberrations originating in the field lens as well as to, together with the field lens, contribute to the light deflection.

Figs. 18 to 21 illustrate four different positions of the projector 10 in relation to a front side 11 and rear side 11' of a projection screen. The screen can be used for projection on both sides 11 and 11'. When the front side 11 of the screen is used, the projector 10 is positioned at a corner with the symbol H1. When the front side 11 of the

screen is turned upside down, an arrangement of the projector 10 in a position in the room which is diametrically opposite to the front side 11 of the screen can be provided. Consequently, two different positions of the projector 10 can be provided. When the rear side 11' of the screen is used, the projector 10 is positioned at the corner indicated with the symbol H2. When the rear side 11' of the screen is turned upside down, an arrangement of the projector 10 in a position in the room which is diametrically opposite to the rear side 11' of the screen can be provided. In this manner, two additional positions of the projector 10 can be obtained. The symbols H1 and H2 are indicated with H1' and H2' respectively when they are on the back side of the screen.

The term 'optically orthogonal' relates to planes or lines, that would be mathematically orthogonal if no plane mirrors were in-between them.

The term 'optically parallel' relates to planes or lines, that would be mathematically parallel if no plane mirrors were in-between them.

Although the shown embodiments of the present invention have been described in detail with reference to the appended figures, it should be realized that the invention is not limited to these specific embodiments and that different changes or modifications can be obtained by a person skilled in the art, without departing from the scope of the invention.

Claims

1. A screen (11) for projection, *characterised in* that the screen (11) is made out of an irregular surface (43), which is either light-absorbing or has been coated with a light-absorbing film (42), which in turn has been coated with a filter (41), that the Fourier transform of the irregular surface (43) may provide a significant spectrum with considerably higher frequencies than the frequencies which are obtained at Fourier transformation of the pixel structure projected on the picture and that the reflection factor (8) for the filter (41) is higher for the wavelengths which correspond to the wavelengths of the illuminating light (R,G,B) than for the wavelengths outside of the wavelengths of the illuminating light.

2. A projection screen (11) according to claim 1, *characterised in* that the light-absorbing layer (42) of the screen is designed with a large number of facets (45a,45b) per pixel with a random distribution of the angles of inclination of the facets, that the inclination of the facets is within certain intervals, chosen so that light is principally directed towards the place in the room where the viewers' eyes mainly will be located.

3. A projection screen (11) according to any of claims 1 and 2, *characterised in* that the relation between the reflection factor (8) of the filter (41) at the illumination wavelengths (R,G,B) and the reflection factor of any wavelength between the illumination wavelengths R,G,B is larger than 1,4.

4. A projection screen (11) according to any of claims 1 to 3, *characterised in* that the screen (11) can be turned upside down for the positioning of the projector (10) at a diametrically opposite position in the room in relation to the front side of the screen (11).

5. A projection screen (11) according to claim 4, *characterised in* that the screen can be turned back to front, wherein the rear side of the screen (11') can be used for two additional positions of the projector (10).

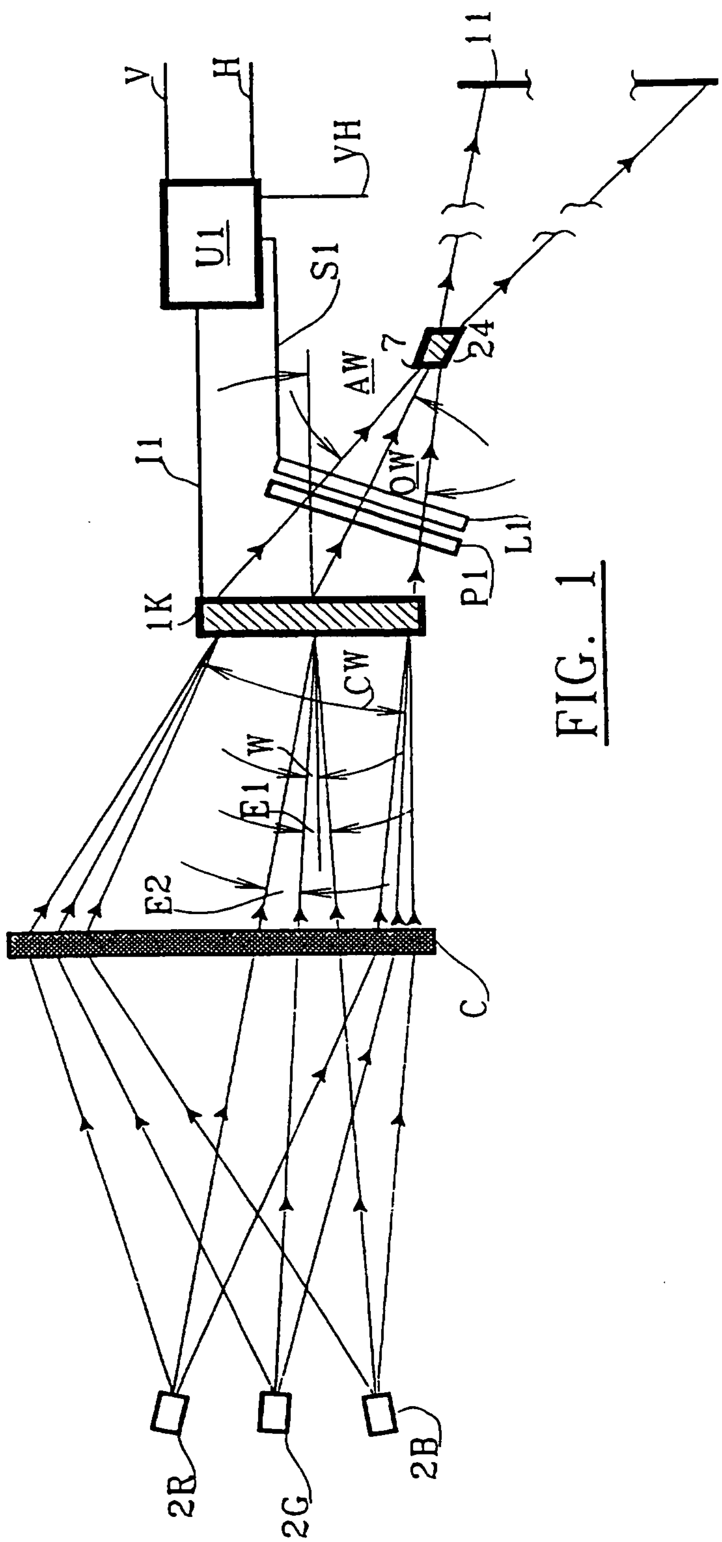


FIG. 1

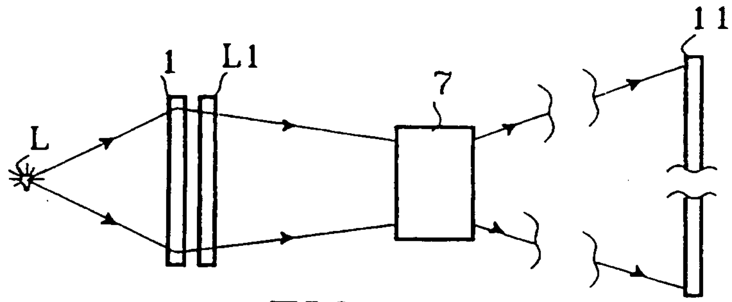


FIG. 2

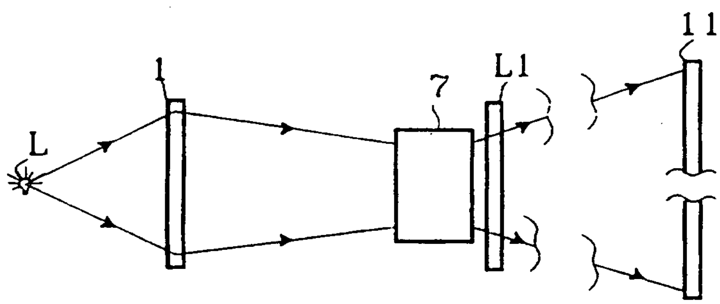


FIG. 3

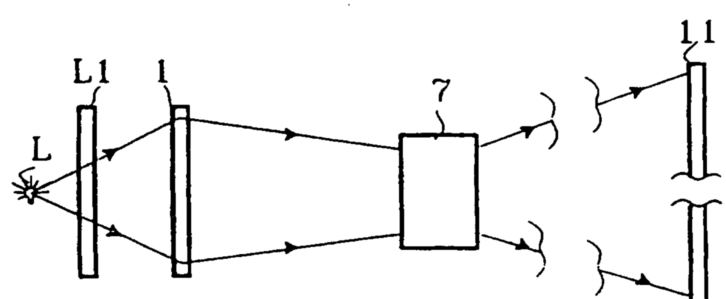


FIG. 4

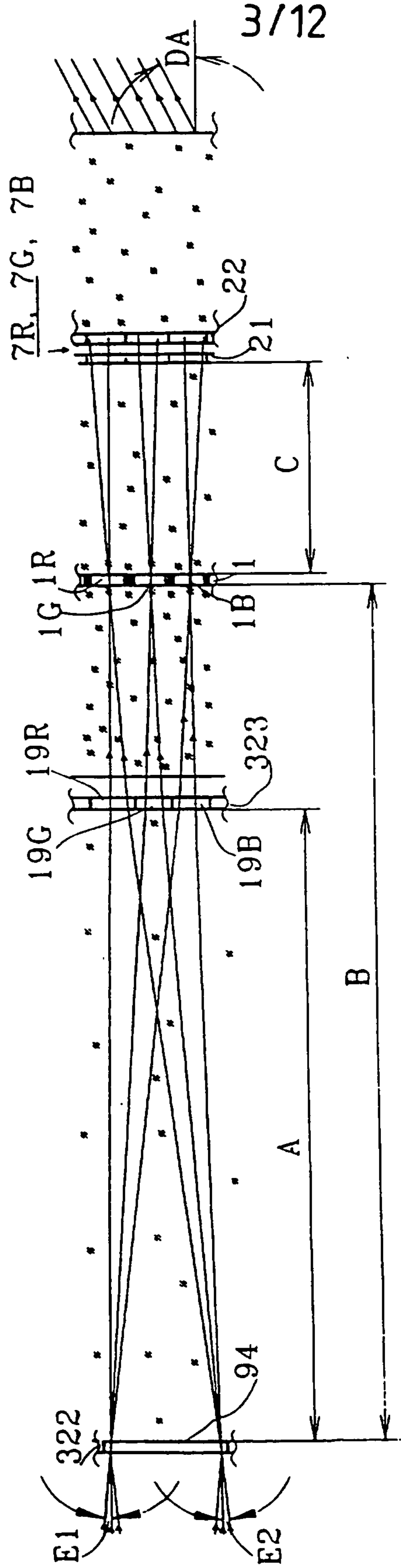


FIG. 5

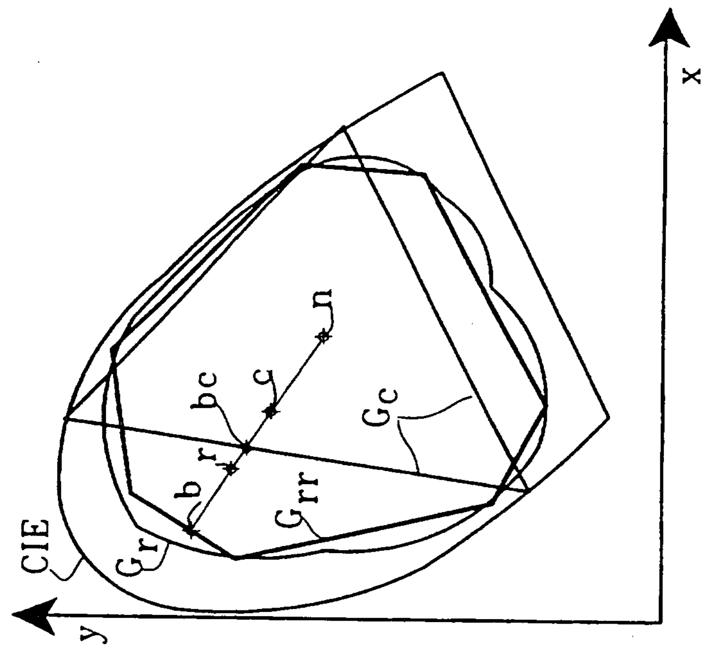


FIG. 7

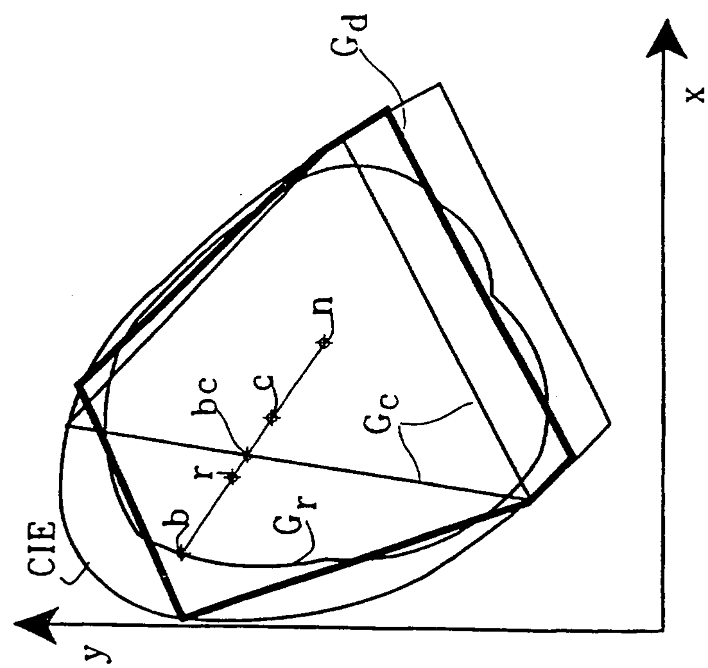


FIG. 6

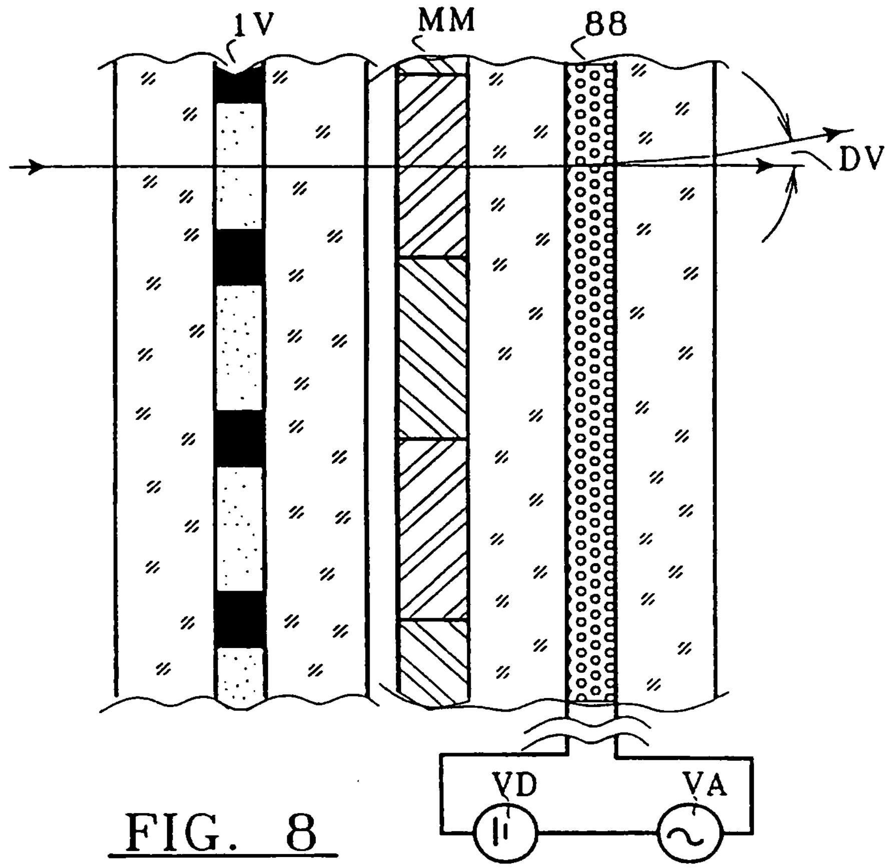


FIG. 8

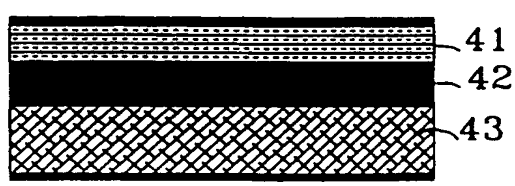


FIG. 9

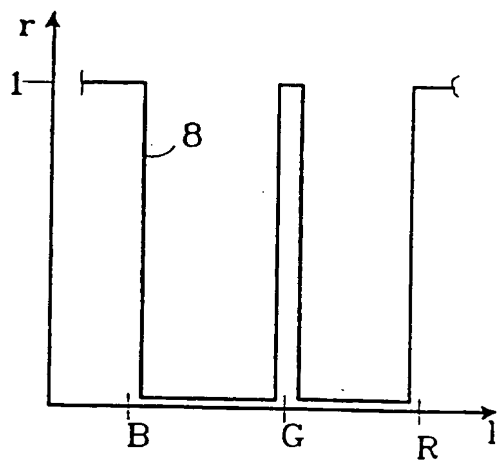


FIG. 10

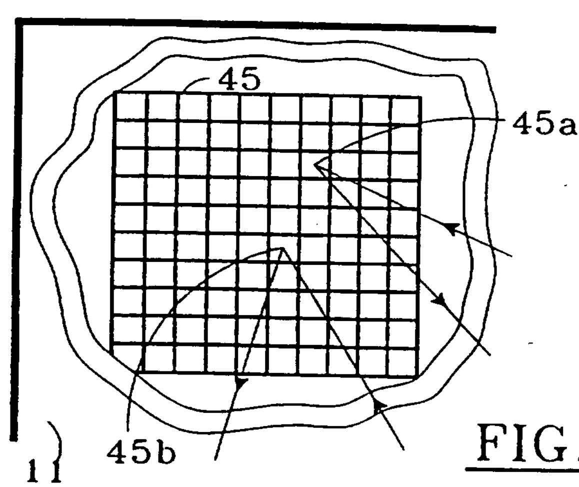
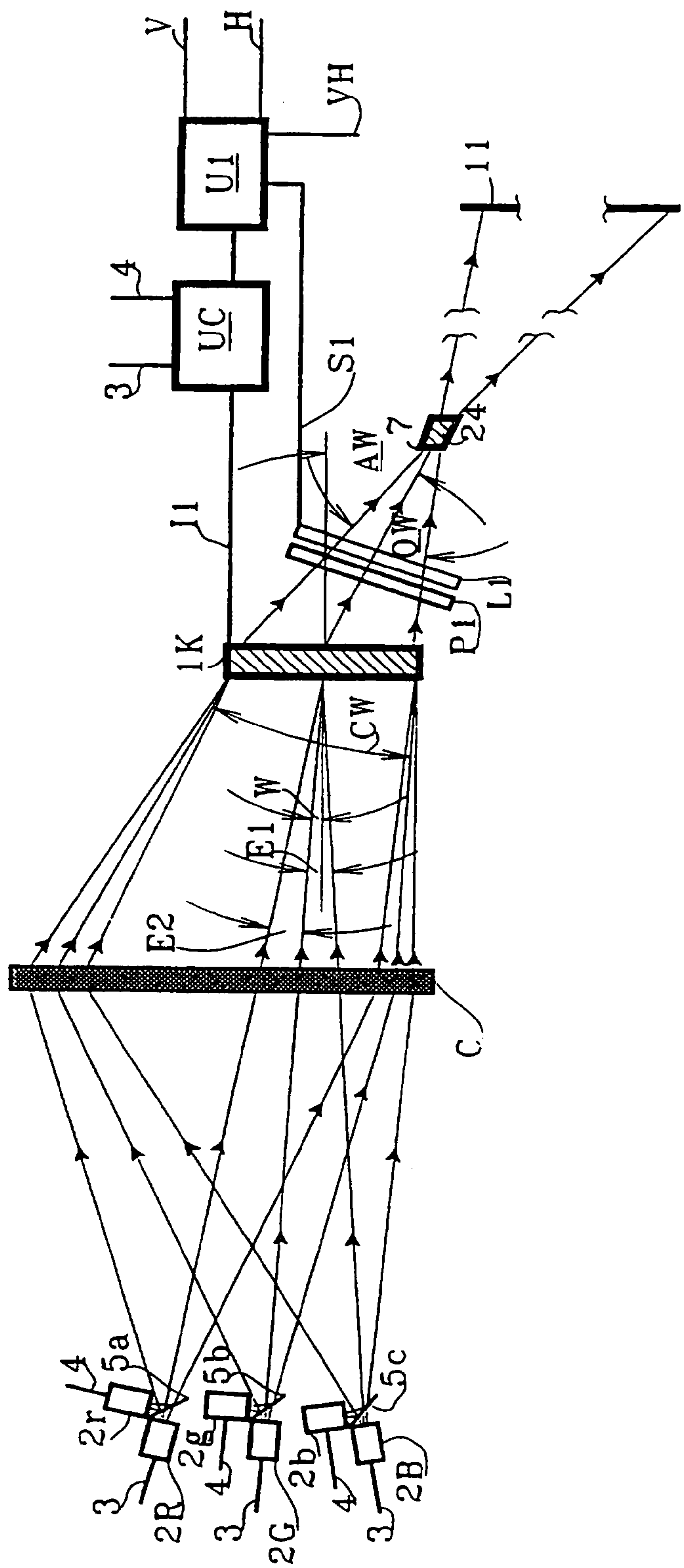


FIG. 11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H
VH
U1
UC
3
4
S1
AW
7
24
11
I1
1K
OW
L1
P1
CW
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E1
E2
C
5a
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5c
2r
2g
2b
2R
2G
2B

FIG. 12

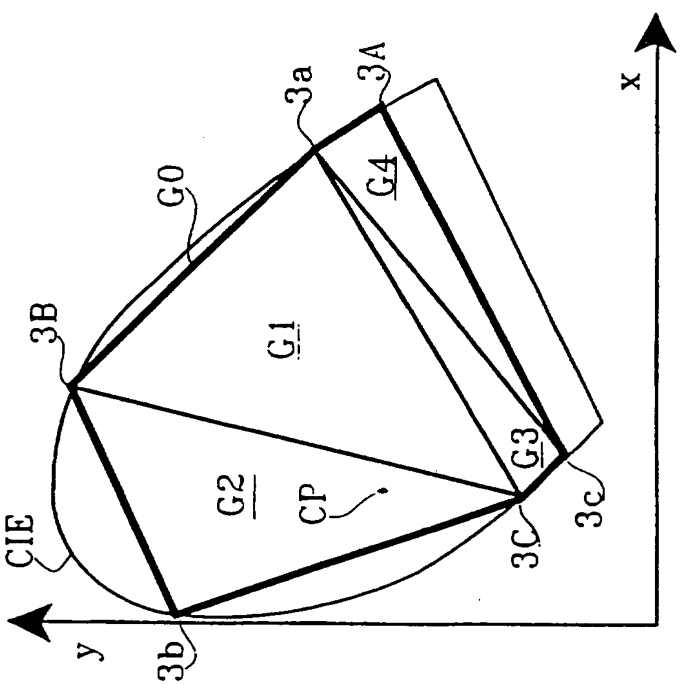
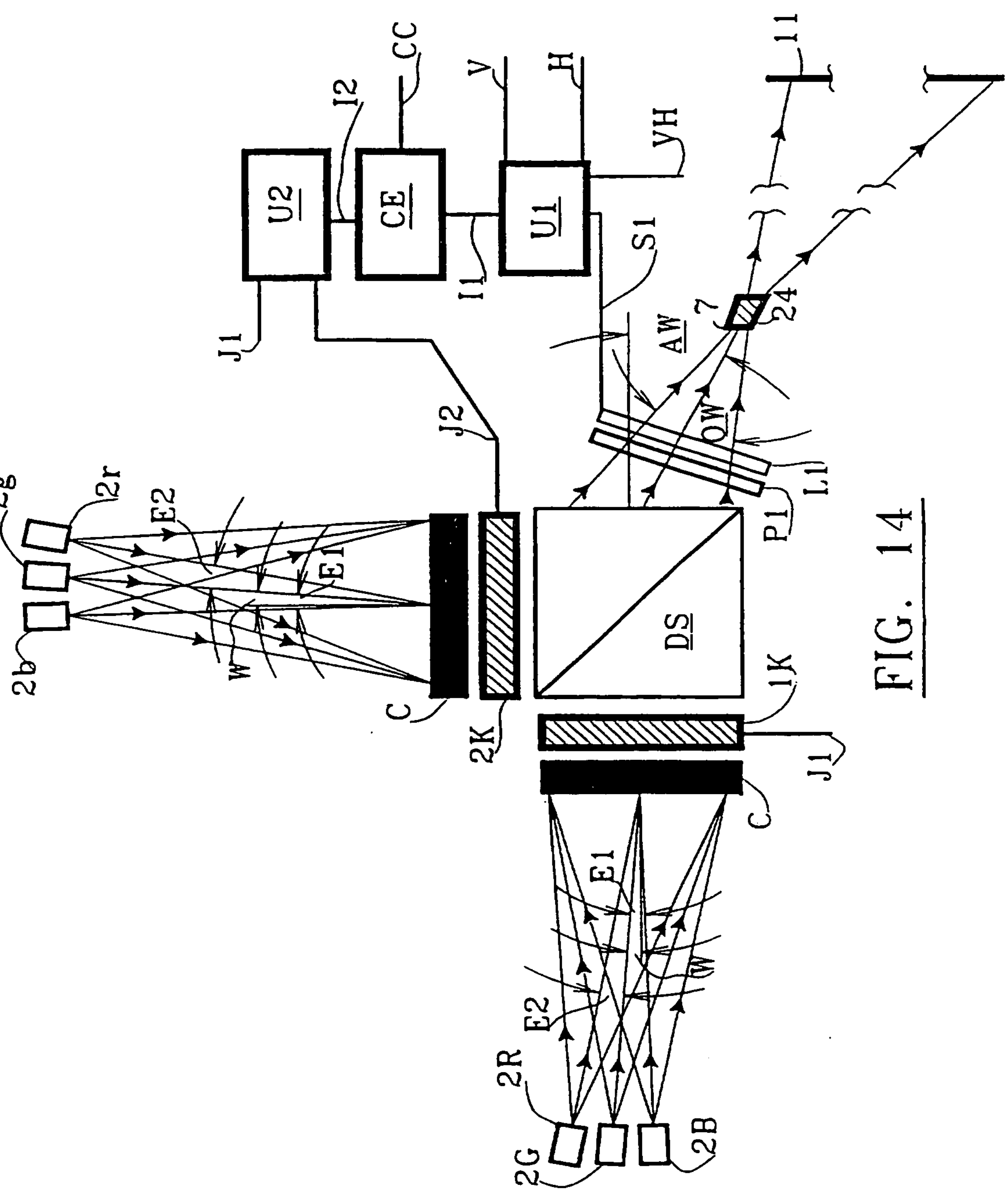


FIG. 13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U1
CC
I2
V
H
VH
I1
S1
J1
J2
AW
OW
7
24
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DS
1K
2K
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2R
2G
2B

FIG. 14

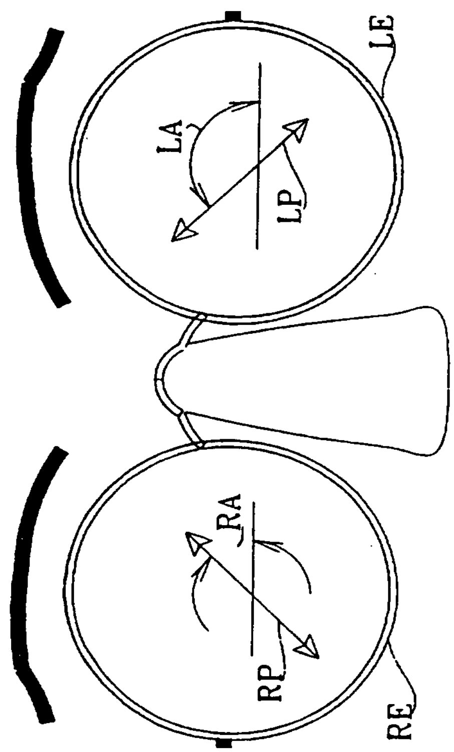
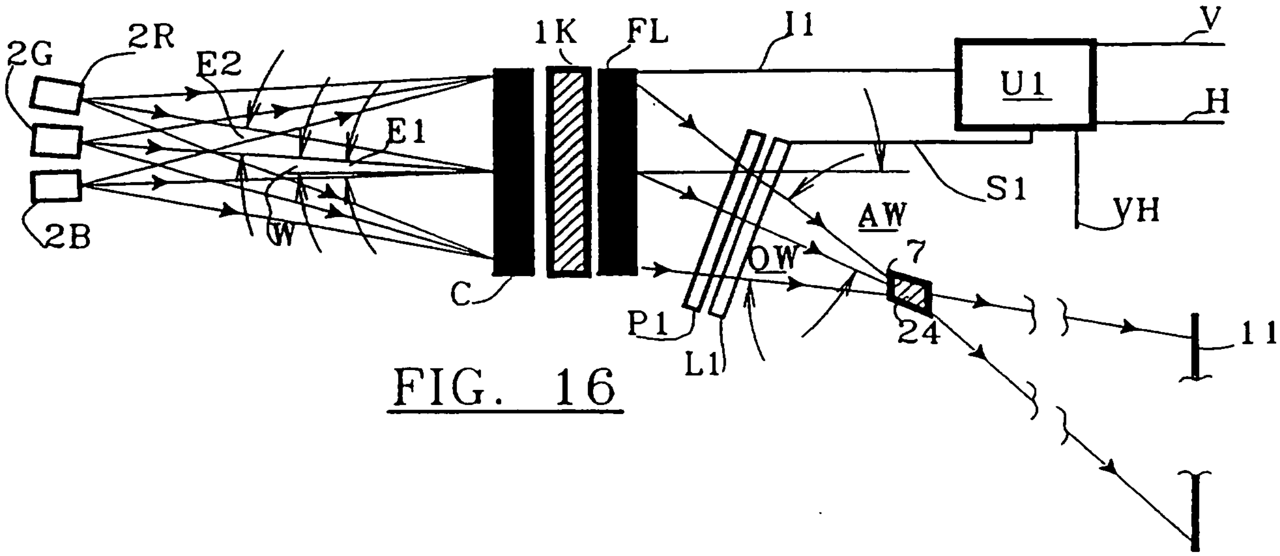


FIG. 15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E2
E1
2B
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1K
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U1
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P1
L1
11

FIG. 16

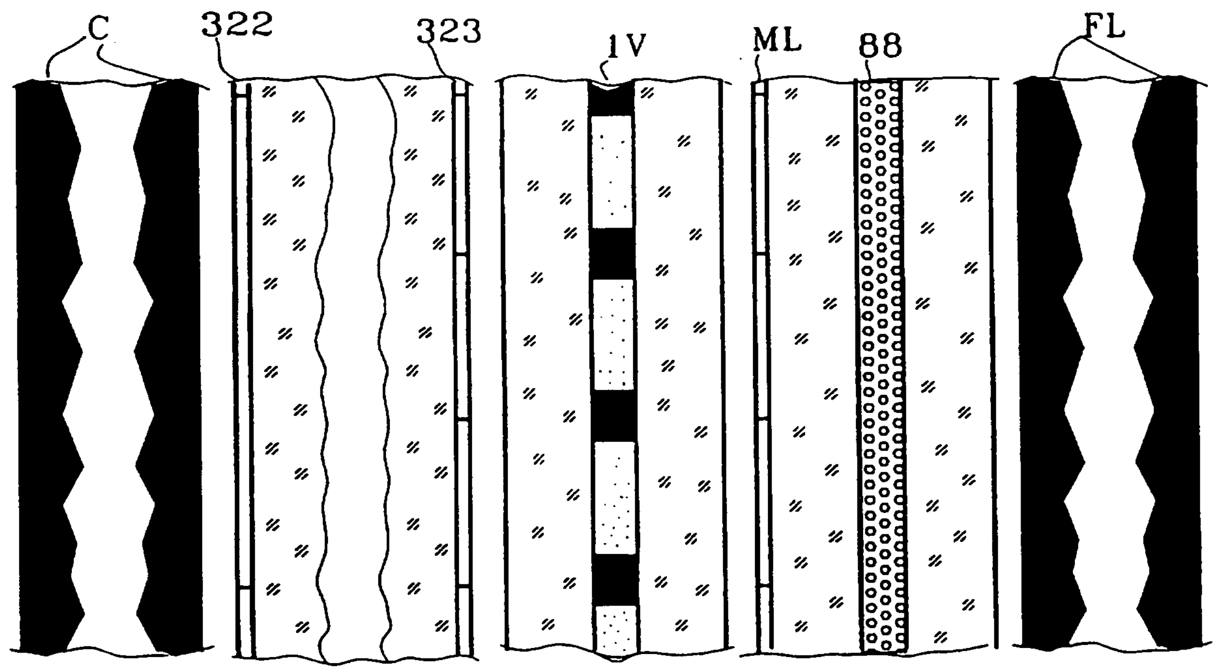
C
322
323
1V
ML
88
FL

FIG. 17

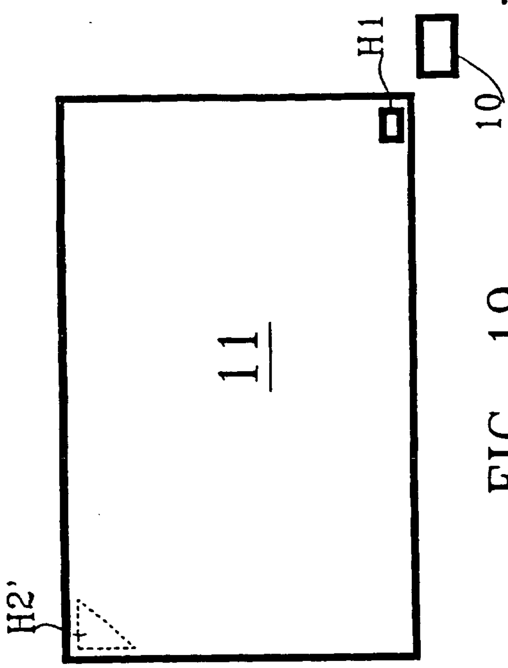

FIG. 19

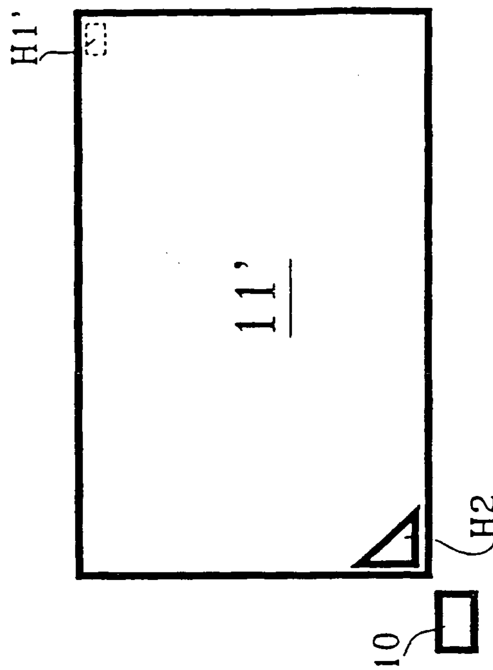

FIG. 21

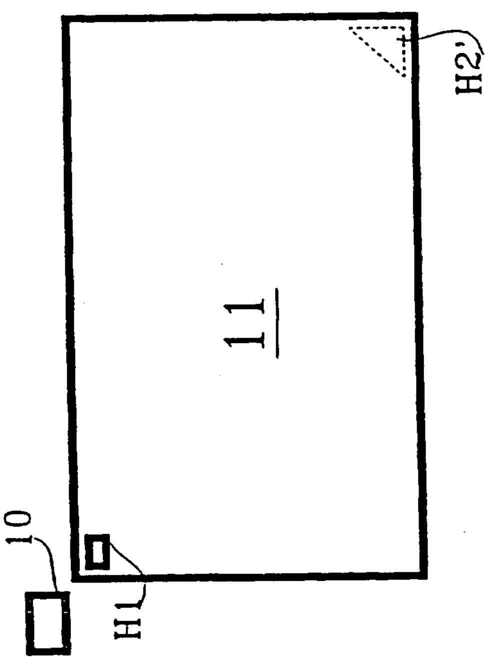

FIG. 18

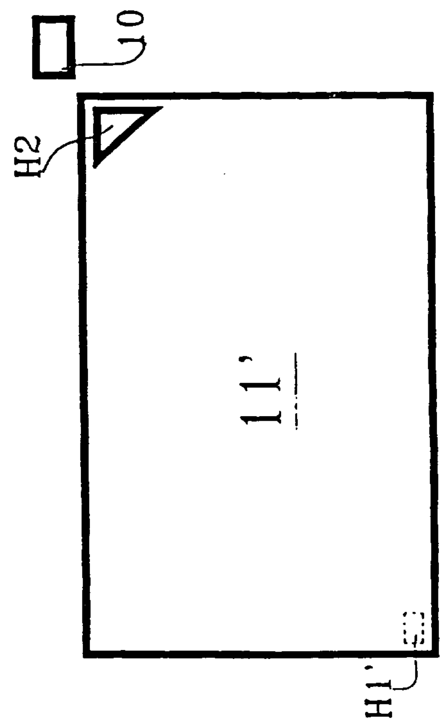

FIG. 20

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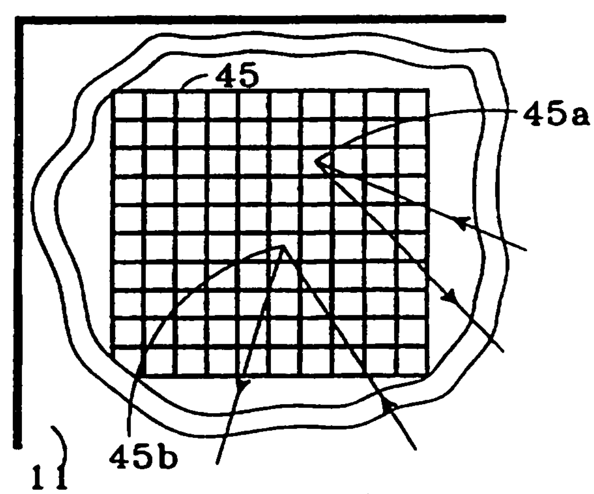
(57) Abstract

A screen for projection (11) being made out of an irregular surface (43), which is either light-absorbing or has been coated with a light-absorbing film (42), which in turn has been coated with a filter (41), wherein the Fourier transform of the irregular surface (43) can provide a significant spectrum with considerably higher frequencies than the frequencies which are obtained at Fourier transformation of the higher pixel structure projected on the picture and wherein the reflection factor (8) for the filter (41) is higher for the wavelengths which correspond to the wavelengths of the illuminating light (R, G, B), than for the wavelengths being outside the wavelengths of the illuminating light.



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LK	Sri Lanka
LR	Liberia
LT	Lithuania
LU	Luxembourg
LV	Latvia
MC	Monaco
MD	Republic of Moldova
MG	Madagascar
ML	Mali
MN	Mongolia
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MX	Mexico
NE	Niger
NL	Netherlands
NO	Norway
NZ	New Zealand
PL	Poland
PT	Portugal
RO	Romania
RU	Russian Federation
SD	Sudan
SE	Sweden
SG	Singapore
SI	Slovenia
SK	Slovakia
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TD	Chad
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TT	Trinidad and Tobago
UA	Ukraine
UG	Uganda
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VN	Viet Nam

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 96/00019

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G03B 21/60
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9422049 A1 (OPTICA NOVA ONAB AB), 29 Sept 1994 (29.09.94), page 2, line 10 - line 15; page 3, line 11 - line 13, claims 1,2,4 --	1,2,3
A	DE 2214638 A (HUBBARD, NOEL KIRKPATRICK), 12 October 1972 (12.10.72), figure 3, claims 1-4 --	1
A	Patent Abstracts of Japan, Vol 14,No 72, P-1004, abstract of JP, A, 1-289940 (SEIKO EPSON CORP), 21 November 1989 (21.11.89) --	1
A	DE 2718065 A1 (SCHUDEL, CONRAD R.), 10 November 1977 (10.11.77), figure 3A, claim 1 --	1

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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Date of the actual completion of the international search	Date of mailing of the international search report
24 July 1996	25 -07- 1996
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Herman Phalén Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT
Information on patent family members

01/07/96

International application No.
PCT/SE 96/00019

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO-A1-	9422049	29/09/94	NONE		
DE-A-	2214638	12/10/72	BE-A,A-	781336	17/07/72
			FR-A,A-	2131698	10/11/72
			NL-A-	7204111	03/10/72
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			JP-A-	52130325	01/11/77